IMPLICATIONS OF A GRAVITY SURVEY FOR THE FORMATION MECHANISMS AND STAGE OF EVOLUTION OF TOPOGRAPHIC (STEALTH) CORONAE. S. E. Smrekar[1], and E. R. Stofan[2], [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., MS 183-501, Pasadena CA 91109 (ssmrekar@cythera.jpl..nasa.gov), [2]Proxemy Research, 29528 Farcroft Lane, Laytonsville, MD 20882.

Introduction: A survey of the gravity signature of 34 topographic coronae [1] (previously termed stealth coronae [2]) on Venus has recently been completed [3]. Coronae are small (avg. diameter ~ 300 km) volcano-tectonic features defined by their nearly circular patterns of fractures and are believed to be formed through mantle upwelling [4]. Topographic coronae have the same topographic expression as regular coronae, but have less complete fracture annuli [1,2]. The values of crustal, elastic, and lithospheric thickness found from the analysis of the gravity and topography of the topographic coronae are discussed in [3]. In addition, examination of the admittance signature results in a determination of whether the elastic lithosphere is being loaded from above or below, or both. Alternatively, some coronae exhibit a signature consistent with isostatic compensation at the short wavelengths associated with corona-scale processes. Here we interpret these loading signatures in the context of models of corona formation.

Gravity Survey Results: The admittance spectrum consists of the ratio of the gravity/topography as a function of wavelength, and is sensitive to bending of the elastic lithosphere in response to a load. A different admittance spectrum results depending on whether the load is dominantly applied from above (top loading) or from below (bottom loading). A top loading spectrum increases towards shorter wavelengths whereas a bottom loading spectrum decreases. For the majority of coronae that can be fit with a top loading signature, an isostatic model of compensation, in which the surface topography is supported by variations in crustal thickness rather than by bending of the elastic plate, provides an equally good fit. Seventeen of the coronae studied have a bottom loading signature only, five have both bottom loading at long wavelengths and top loading or isostasy at short wavelengths, and twelve have a top loading or isostatic signature (Figure 1). A bottom loading signature implies that a low density region, such as a plume, is pushing up from below. A top loading signature implies that a mass has been applied to the surface, such as a volcano, and is depressing the original topographic surface as the elastic plate flexes.

In the case of the topographic coronae, the majority of which consist of topographic depressions and rim only coronae, interpretation of loading signatures is not straightforward. There is no obvious source of a top load, such as a large volcano. Although this would suggest that this type of signature is better interpreted as an isostatic signature, there are a few coronae for which only a top loading signature will fit the admittance spectra. An alternate model that fits a 'top loading' spectrum is one in which a high density anomaly at depth causes the surface to be depressed, which we term positive bottom loading. Thus three models can provide an equally good fit to most spectra that increase towards short wavelengths. The bottom loading signature is also puzzling, as one expects a topographic high, not a depression, to form over a low density anomaly that produces a bottom loading signature.

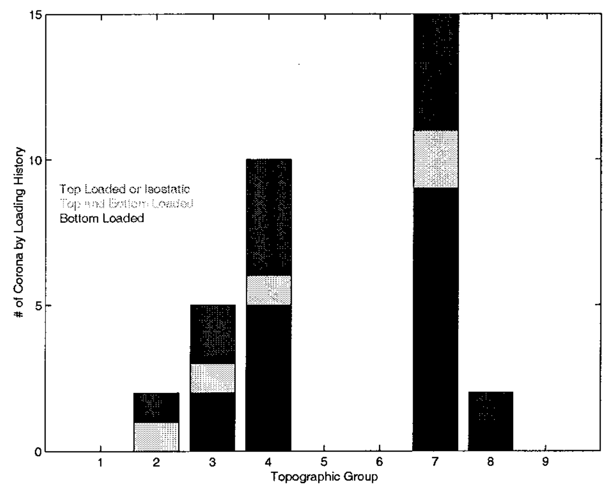

Figure 1. Number of coronae that have different admittance loading signatures as function of topographic group (see text for definitions).

Models of Corona Formation: One of the challenges to modeling the formation of coronae is the very diverse range of topographic forms [5]. The forms were classified into 9 groups: 1) dome, 2) plateau, 3) rim surrounding interior highs or domes, 4) rim surrounding depression, 5) outer rise, trough, rim, inner high, 6) outer rise, trough, rim, inner low, 7) rim only, 8) depression, and 9) no discernable signature. A finite element model of corona formation by small scale upwelling allows for a greater variability of topographic forms by including both delamination of the cold lower lithosphere at the edges of the plume head and thinning of a preexisting depleted mantle layer [5]. Since a depleted mantle layer has a lower density than the lower lithosphere variations in its thickness have the opposite effect of variations in lithospheric thickness. In these models, a depression can be created above a plume in two ways. These two aspects of the model allowed for a wide range of topographic signatures. A depleted mantle layer is the low density residuum left following pressure release melting. Due to the lack of subduction on Venus, a depression will occur above a mantle plume if a thick depleted mantle layer is present. The momentum of a plume head rising through the denser mantle causes it to thin a depleted mantle layer at the base of the lithosphere despite its lower density. Replacement of the buoyant depleted mantle by the plume head, which increases in density as it cools, pulls the topographic surface downward (Fig. 2). Alternatively a depression can be created by inward migration of the delaminating lower lithosphere, where delamination is initiated by the coupling between the plume head and the lower lithosphere (Fig. 2). Another mechanism that could form a depression or rimmed depression is isostatic adjustment of lithosphere thinned by a plume [6,7]. However this mechanism requires quite low lithospheric viscosities, and is thought to be improbable for the Earth. Similarly, this mechanism may not be viable for Venus. The only mechanism that was found to create a rim only corona requires delamination, cessation of the delamination due to thermal equilibration of the cold lower lithosphere with the mantle, and isostatic rebound of either the crust or a depleted mantle layer that thickens due to the delamination (Fig. 2). Coronae in this survey are dominantly rim only and rim surrounding depression (Fig. 1).

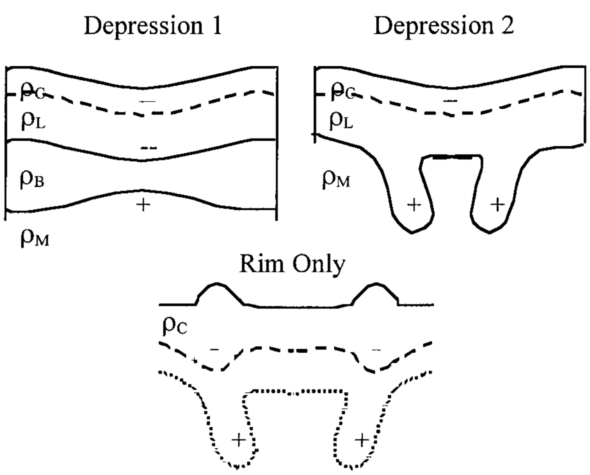

Figure 2. Cartoons describing the formation mechanisms for depressions and rim only coronae modeled in [5]. The top most layer is the crust, the next layer is the thermal lithosphere, and the bottom layer is the mantle. Each layer has a different density. For depression 1, a buoyant depleted layer occurs between the mantle and the base of the thermal lithosphere. Plus and minus signs indicate how deformation of the layers creates excess mass or a mass deficit, respectively. At the point when a rim begins to form, the delamination has stopped due to thermal equilibration of the downgoing lithosphere.

In the context of these models, isostatic rebound of the crustal layer is the most likely source of a buoyant force acting to push the surface up and create a bottom load. Although a plume would also act to push upward on the surface, the surface depression indicates that even if a plume is active, the overall balance of dynamic forces is not positive upward. The processes that form both the second type of depression and the rim only coronae (Fig. 2) occur only once the plume has dissipated. Once the dynamic forces of either the plume thinning a buoyant depleted mantle layer (Depression 1) or delamination (Depression 2, Rim only) die out, the crust is left to isostatically rebound.

The other observed type of admittance spectrum is either a top load or an isostatic signature. An isostatic signature is easily understood as the final state once any crustal flow is essentially complete. If this is the correct interpretation, one would expect coronae with an isostatic signature to be somewhat topographically shallower than those with a bottom loading signature. A top loading signature could be understood in the context of a dynamic load that is actively pulling down on the surface, due to either delamination or thinning of a depleted mantle layer. If this is the correct interpretation, coronae with a top loading signature might be expected to have a deeper interior depth than those with a bottom loading signature.

For domes and plateaus, a bottom loading signature may indicate that a plume is still present. A top loading signature could indicate a late phase following dissipation of the plume, when the topographic uplift is sinking and loading the elastic plate.

Conclusions: The results of the gravity survey indicate that the corona with the same topographic shape can have very different gravity signatures. Along with detailed characterization of individual corona topography and geologic history, these signatures may help distinguish between various mechanisms and stages of formation for coronae. This information in turn will help constrain rates of lower lithospheric recycling, crustal thickness, and the presence or absence of a depleted mantle layer.

References: [1] Tapper et al. (1998) *LPSC XXIX Abstracts on CD-ROM.* [2] Stofan E.R. et al. (2001) *LPSC XXXI Abstracts on CD-ROM.* [3] Comstock, R.L. et al. (2000) *LPSC XXXI Abstracts on CD-ROM.* [4] Stofan E. R. et al. (1997) in *Venus II*, 931-965, and references therein. [5] Smrekar S. E. and Stofan E.R. (1997) *Science, 277*, 1289-1294. [6] Koch, D.M. and Magna, M. (1996) GRL, 23, 225-228. [7] Koch, D.M. and Ribe, N.M. (1989) GRL, 16, 535-538.